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SHELTER THROUGH ARCHITECTURAL DESIGN, THE SHIELDING
REQUIREMENTS INFLUENCE ON FORM.
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FALLOUT PROTECTION CAN BE PROVIDED BY CAREFUL ARRANGEMENT OF ARCHITECTURAL ELEMENTS WITHOUT SPECIFIC FACILITIES FOR THEIR PURPOSE AND WITHOUT INTERFERING WITH NORMAL SPACE USE. CHARACTERISTICS OF RADIATION ARE DISCUSSED AND ILLUSTRATED PRINCIPLES OF SHIELDING DESIGN WITH RESPECT TO DISTANCE, GEOMETRY, AND TIME ARE GIVEN. (JT)

TR-44
APRIL 1967

SHELTER THROUGH ARCHITECTURAL DESIGN

THE SHIELDING REQUIREMENTS INFLUENCE ON FORM

OFFICE OF CIVIL DEFENSE

SHELTER THROUGH ARCHITECTURAL DESIGN
THE SHIELDING REQUIREMENTS' INFLUENCE ON FORM

Objective and knowledgeable design approaches coupled with accurate shielding calculations can result in the incorporation of fallout gamma radiation protection into space without imposing upon any of the normal, day-to-day functions of that space. A shelter need not be recognizable as such. Fallout shelter spaces may be included in building types of every category without adversely affecting appearance or function and, in some cases, at no additional cost.

Almost every building shields against fallout gamma radiation, though some are better shields than others. Surveys have revealed shelter spaces for millions of Americans in existing buildings. Many other buildings were found that had weak points which could have been strengthened or avoided with little modification during design. By what criteria are buildings judged to be good or poor shelters? To explain some of these criteria, it is necessary to review briefly the behavior of radiation and fallout.

RADIATION BEHAVIOR INFLUENCING DESIGN

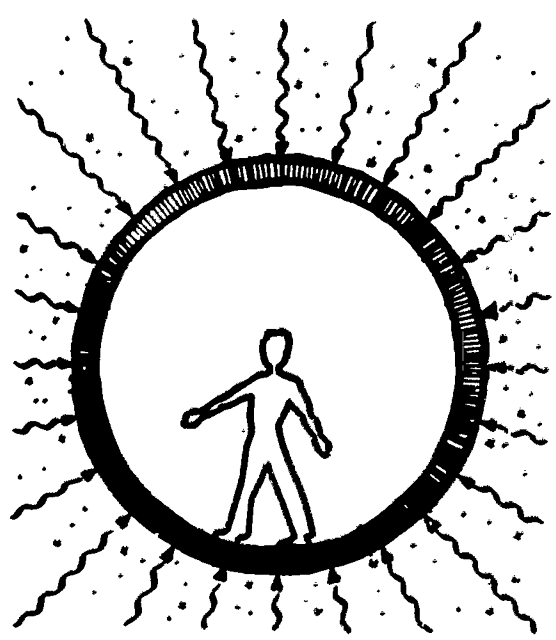
Gamma radiation, which is pure energy, cannot be detected through our human senses; it can be neither seen, felt, smelled, tasted nor heard. To detect this radiation,* it is necessary to use a geiger counter or other electromechanical means which may also measure its intensity.

* The term radiation here refers to gamma radiation. Alpha and beta particles from fallout are not considered because they do not obey the same laws.

As with light, gamma radiation travels in a straight line from its source until it interacts with matter. The source may be infinitely small (i.e., a dust particle) and there may be an infinite number of sources as there is with fallout. The radiation should not be confused with its sources which, in the case of fallout, are radioactive particles attached to matter. Gamma radiation, traveling in straight lines, differs from the radiating particles which, affected by both air currents and gravity, may drift or be blown erratically to settle and collect on horizontal surfaces and to pile up in corners and depressions

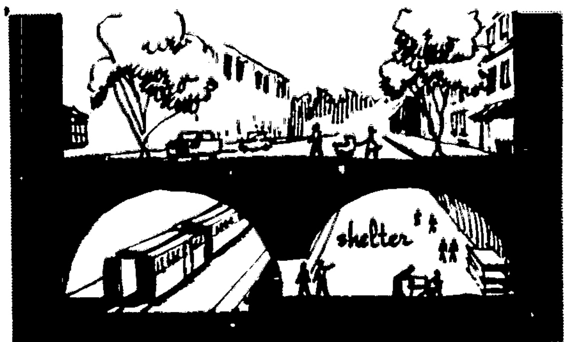
IN THE EVENT OF NUCLEAR ATTACK, ANY AREA OF THE UNITED STATES COULD FIND ITSELF IN THE PATH OF CLOUDS OF RADIOACTIVE FALLOUT. RATIONAL DESIGN CAN PROTECT MAN AGAINST RADIOACTIVITY. JUST AS DESIGN, IN SOME AREAS, IS AFFECTED BY FORCES OF EARTHQUAKES, HURRICANES OR EXTREME SNOWLOADS, SO ALSO MAY ARCHITECTURE BE LOGICALLY SHAPED BY THE NEED TO SHIELD HUMANS FROM GAMMA RADIATION. THIS NEED NOT MEAN THE DESIGN AND CONSTRUCTION OF FALLOUT SHELTERS PER SE, BUT SIMPLY THE APPLICATION OF APPROPRIATE DESIGN CRITERIA TO BUILDINGS TO BE CONSTRUCTED FOR OTHER PURPOSES. MANY SUCH CRITERIA ARE PRESENTED HERE.

TO PROVIDE IMPETUS TO DESIGN FREEDOM, BROAD GUIDELINES RATHER THAN SPECIFIC COMPUTATIONS ARE GIVEN. WHILE SUCH GENERALIZATIONS ARE NECESSARY, NOT TO BURDEN THE DESIGNER IN PRELIMINARY STAGES, THE DETERMINATION OF THE DEGREE OF PROTECTION AFFORDED MUST BE LEFT IN THE HANDS OF COMPETENT CONSULTANTS.

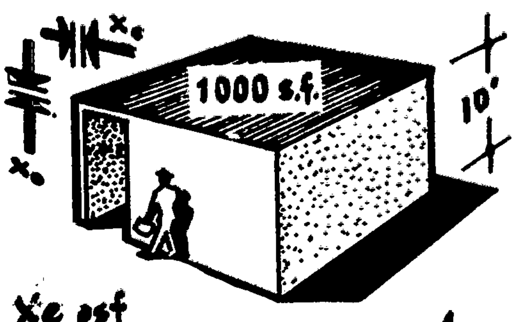


THE SHIELD should have considerable thickness and density – in reducing radiation, it provides protection –

Each dust particle = a tiny source of radiation



A less dense material (such as earth) may shield if thickness is increased -



Xc psf ↓ / Xo psf ← / PF's

Xc psf \ Xo psf	50	100	200	300
50	4	5	5	5
100	7	12	15	15
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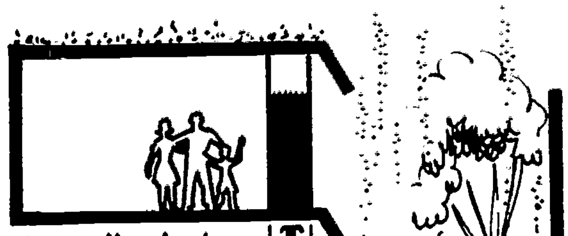


Water wall enclosed w/ glass: Thickness = 2½ x concrete

and at intersections of horizontal and vertical planes. Radiating particles congregate on the roof and ground, becoming solid planes of radiation, more "alive" than the surrounding atmosphere itself through which they fall. This accumulation of radioactive matter is called "contamination."

Unlike light, gamma rays tend to penetrate solid, opaque masses of materials which absorb radiation according to their unit weights or "masses." Some rays, in passing through mass, are "scattered"—that is, their directions and energy are changed. These characteristics account for shielding criteria and become architectural form-determinants.

SHIELDING PRINCIPLES

Protection from fallout may be achieved in the design of buildings through the application of four basic form principles—barrier and geometry shielding, distance and time.

BARRIER SHIELDING: Affording protection by absorption or capture of radiation, a shield's governing characteristics are thickness and density, and the more mass or unit weight the better. A less dense shield will have to be increased in thickness. One of the most economical shielding materials is concrete, but any masonry—singly or in combination—or even a thickness of earth or water is capable of attenuating or blocking radiation. Slip-form, tilt-up, load-bearing, and precast masonry panels are all likely to provide good shielding ability with economy.

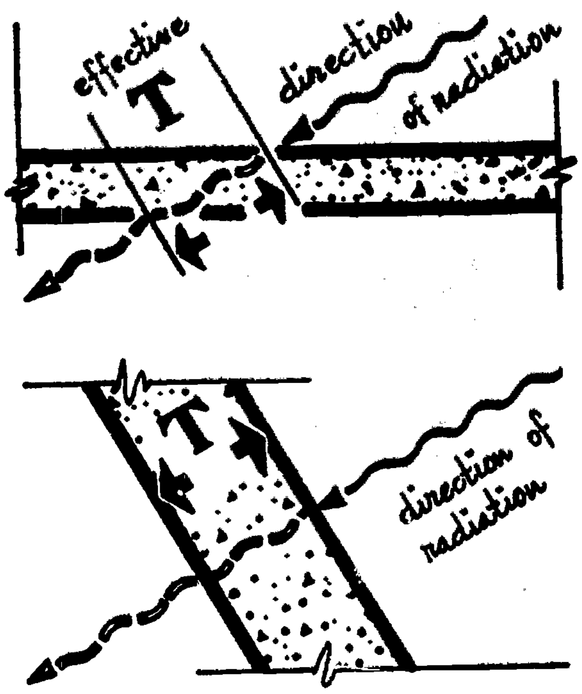
While water could be used as a shield to offer a view of the outside, a water wall enclosed by glass would be an elaborate and costly solution. It is a less expensive solution, however, than an equivalent thickness of solid glass. A flat overhead canopy-like water tank that is full could shield. A layer of stored bulky material or mechanical equipment (overhead or to the side) would seem to be a logical bulwark, but caution would reveal that its density may vary greatly in space and time. Shielding then, should normally be of a permanent, immovable nature.

Varying barrier thicknesses, such as with pan construction or a shell whose thickness is not constant, can often be averaged or "smeared." With a folded-plate roof or undulating wall, the total material involved should equal that in a flat-plane shield. Where radiation is directional and strikes the shield at an angle, the effective shield thickness is increased.

The handling of combinations of floors, roof slabs and walls surrounding all types of spaces adjacent to or over and under the shelter will enhance shielding. The protection value of each is cumulative. Some current buildings such as Harvard's educational building by Caudill, Rowlett, and Scott, Yale's architecture building by Paul Rudolph, Eero Saarinen's conglomerate-masonry dorms are quite in sympathy with the application of the barrier shielding principle.

Consider barriers an average thickness.

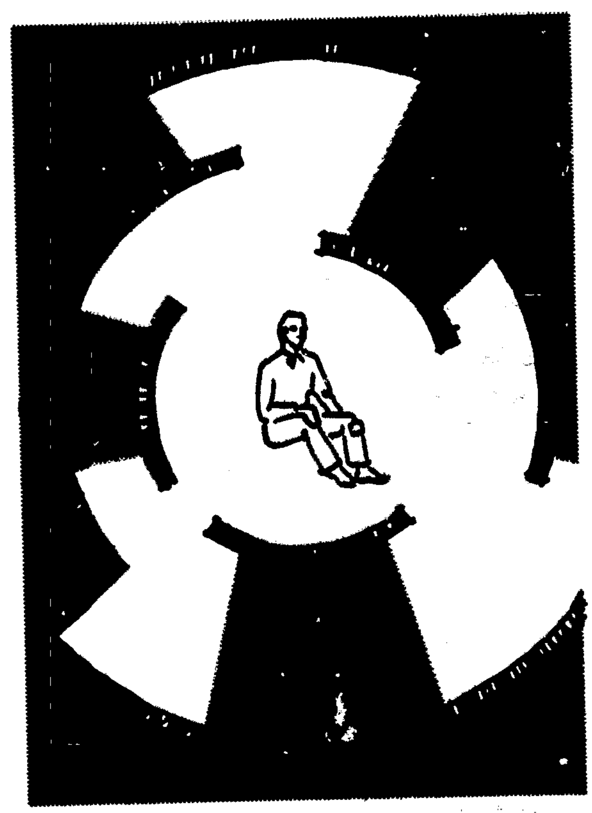
GEOMETRY SHIELDING: Radiation reaching any given point in a building may come from all sides and penetrate walls, roofs and floors, so the positioning of these elements with relationship to each other (all of which shield) may be fully as important as their unit weights. An arrangement of staggered baffles set up in a simple maze (similar to Indiana University's Clowes Memorial Hall Auditorium by Evans Woolen) can provide light and air with protection. A double layer of giant louvers at right angles to each other could serve. This is similar to the fresh air louver into a darkroom which admits air but blocks light. Some of Louis Kahn's "building within a building" schemes, with perforated concentric enclosures, approach quite workable solutions.



These shields are of equal value, though one is half the thickness of the other.

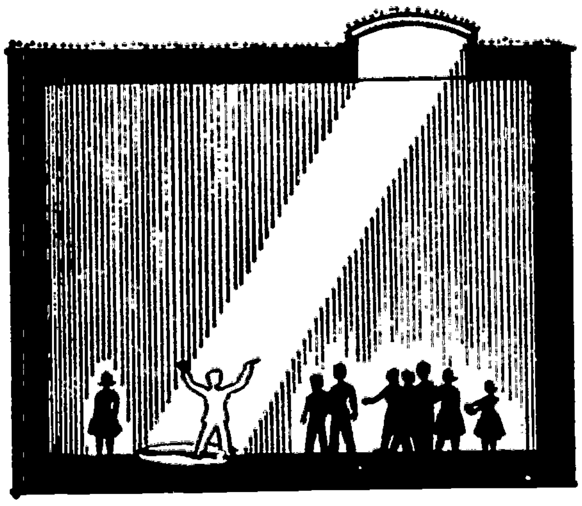
The handling of openings is critical. Entrances to lobbies or corridors may be shielded to a large degree by stairways or courtyard walls. Since reflection (or bouncing) of rays is secondary, another simple solution to decrease direct entrance or "streaming" of rays of radiation is to provide a right-angle turn (vertically or horizontally) between the entranceway and the interior shelter space.

Though windows need not be eliminated, extreme care must be exercised in their placement. Ingenious designs from OCD shelter competitions show that careful placement of shields permits surprising expanses of fenestration.

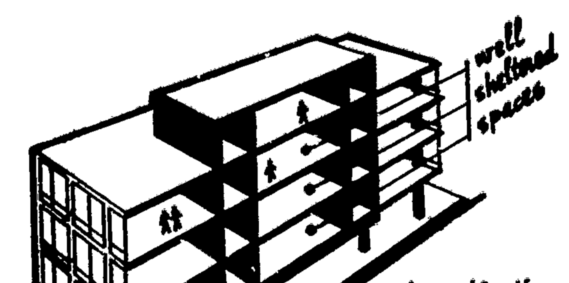


Light wells and skylights are not out of the question if their exposed areas are small and their heights above the occupancy level are sufficient.

An open-ended corridor or other horizontal aperture, provided it is discreetly sized and remotely located, may provide a psychological outlet. Unglazed openings, if provided with maze shielding, are also possible. Consensus of many research projects along this line is that infiltration of radioactive particles borne by natural or mechanical ventilation is likely to be negligible. If necessary, it can be swept up and removed.

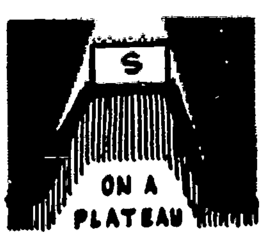


A small skylight is sometimes possible...



A combination of peripheral curtain walls (keeping fallout at a distance) & corridor walls (with aggregate mass-thickness) may offer adequate protection at no additional cost...

Protection from the greatest normal source of radiation - the contaminated ground plane - w/ site planning



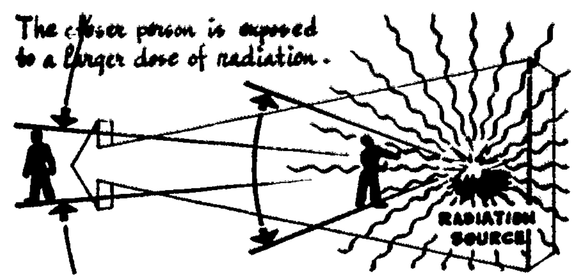
It is possible for shielding to be physically removed or separated from the shelter space. This is called "mutual shielding." Two adjacent structures may shield each other if they are close enough and ground area between them is limited, thus reducing the size of the contaminated plane. Their positioning, in section and plan, must be precise.

Blocks of building elements may be so massed as to provide a protected core. Montreal's Place Ville Marie, some of the Scarborough College complex (University of Toronto), and many rotunda spaces would approach such a scheme. Any hollow well, covered court or patio will provide some protection if surrounded by a ring of building mass. The core of Wright's old Larkin Building in Buffalo was a likely space.. The fallout on the roof, however, must also be considered.

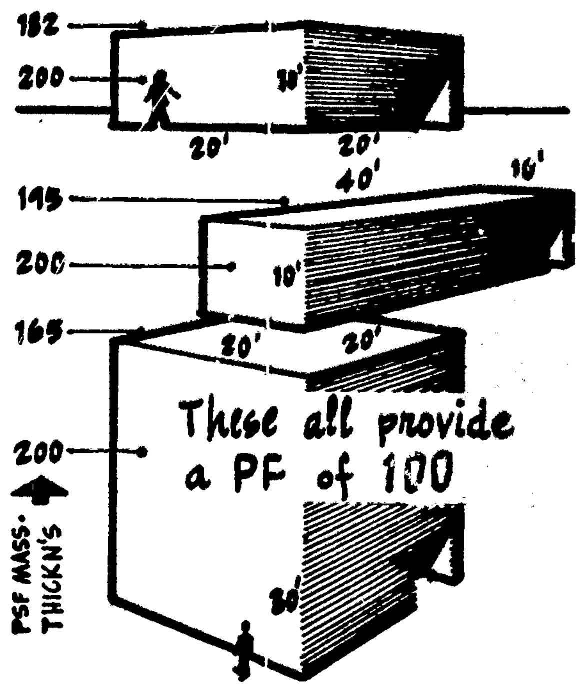
Shielding through geometry should extend to planning of the site. Retaining walls, planters and earthen berms around openings can minimize ground surface radiation—normally the greatest source—and permit lessening (or elimination) of barriers built specifically for shielding. A slight slope away from the building on all sides can decrease radiation from that plane to the building's ground floor. Siting the building against a hillside, on a plateau or in a chasm would utilize the most inexpensive shielding material of all—earth. And of course any depression or submersion of the building below grade will rapidly reduce radiation to the interior. Many basements, even with a minimum of windows and a portion of aboveground exposure, provide adequate shielding for all but the most intense radiation. A moat or encircling depression around the building would allow fallout to be deposited in a trench where it would decay with little penetration of harmful radiation into upper shelter spaces. Paolo Solari's earth sculpture forms would contribute very nicely to the shielding capability of structures if carefully thought out and executed in terms of the radiation shielding function.

DISTANCE: Protection may be afforded through physical separation of the radiating particles from the shelter. Layers of air may, through attenuation of radiation, afford protection. Theoretically, a large Buckminster Fuller geodesic dome or even a giant inflated balloon enclosing a neighborhood (if unaffected by atomic blast) could radically reduce the need for shielding immediately surrounding a shelter space.

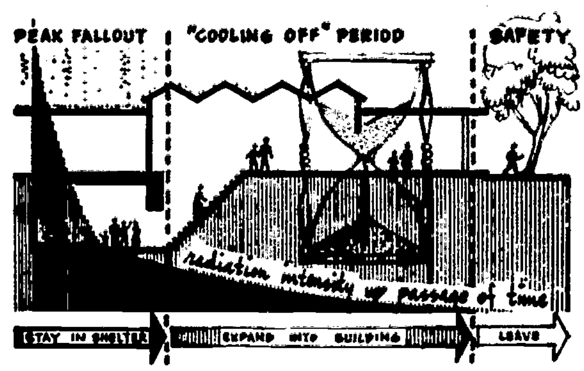
While a smaller shelter permits a maximum reduction of peripheral shielding (because of the smaller space enclosed), it requires a shield of greater thickness. The closer proximity of the radiation sources requires the envelope to assume a bunker-like character.

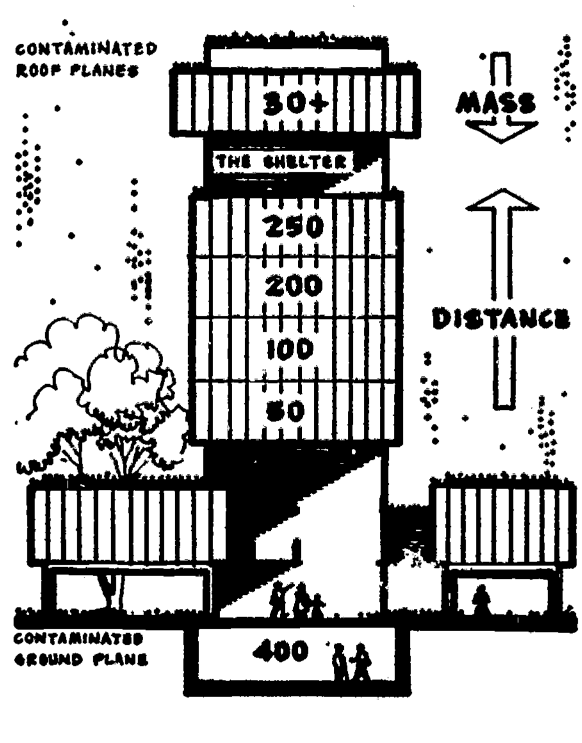


TIME: The rate of emission of radiation by fallout decreases rapidly following detonation. Taking advantage of this decay characteristic, the architect may lay out his shelter and its surroundings to permit a modulated expansion of shelter occupants after the initial "hot" period. Spreading out into more spacious quarters with thinner screens as the radiation intensity decreases would provide an important psychological boost. Following a detonation, fallout accumulates within a predictable period of time. Fifty to 70 percent will be within 24 hours; the remainder will be delayed, depending on high altitude winds, size of particles, proximity to ground zero, and other factors.



With these notes on radiation behavior and shielding principles, the architect has some simplified design tools to add to his general knowledge of functional, structural and mechanical considerations. These rough rules-of-thumb are adequate only for preliminary design. Just as complete design processes are necessary in the structural and mechanical aspects of every building, so are computations necessary in evaluating each shelter design.





CHECKLIST OF BASIC DESIGN TOOLS

Barrier:

1 Use precast, tilt-up, slip-form and bearing walls instead of lighter-weight materials.

2 Work with concrete tees and prestressed masonry units instead of light-weight floor and roof assemblies; detail roof fills.

3 Arrange multiple thicknesses of walls, floor, and roof slabs surrounding the shelter space.

4 Employ courtyard walls, planters and neighboring buildings for shielding.

5 Fill hollow blocks with sand or gravel, or otherwise increase weights (mass thickness) of shielding walls.

Geometry:

6 Place shelter in inner core corridor area or basement.

7 Form earth berms, moats, pedestals, platforms or other sculptured earth shapes; slope grade away from building.

8 Carefully position and proportion overhangs and fascias.

9 Provide right-angle turns at entrances; stagger openings to obviate radiation's "streaming" in.

10 Reduce window areas; raise sill heights to shield against ground radiation.

Distance:

11 Enlarge building envelope; position shelter remotely from peripheral walls; raise a canopy high above sheltered floor.

12 Place shelter in upper two-thirds of a multistory structure, with two or more floors above.

Time:

13 Surround maximum protected space with less shielded expansion areas—an arrangement called a "graded shelter."

14 Line shelter with food storage or other usable stock; its use (and removal) would coincide with the diminishing need for shielding.

15 Make use of pools of water outside shelter to act as catch basins for fallout which would settle to bottom and be attenuated by the mass of the water covering it.

Developed for OCD by Prof. Samuel T. Lanford, Assistant to the Chairman, University of Illinois, Department of Architecture

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